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ORIGINAL RESEARCH

Preoperative Transthoracic Echocardiography Predicts Cardiac Complications in Elderly Patients with Coronary Artery Disease Undergoing Noncardiac Surgery

Zijia Liu[1], Guangyan Xu[1], Yuelun Zhang[2], Hanyu Duan[3], Yuanyuan Zhu[4], Li Xu[1]

[1]Department of Anesthesiology, Peking Union Medical College Hospital, Chinese Academy of Medical Sciences and Peking Union Medical College, Beijing, People's Republic of China; [2]Medical Research Center, Peking Union Medical College Hospital, Chinese Academy of Medical Sciences and Peking Union Medical College, Beijing, People's Republic of China; [3]Department of Anesthesiology, Tibet Autonomous Region People's Hospital, Lhasa, People's Republic of China; [4]Department of Cardiology, Peking Union Medical College Hospital, Chinese Academy of Medical Sciences and Peking Union Medical College, Beijing, People's Republic of China

Correspondence: Li Xu, Department of Anesthesiology, Peking Union Medical College Hospital, Chinese Academy of Medical Sciences, Peking Union Medical College, Beijing, 100730, People's Republic of China, Tel +86 10 6915 2020, Fax +86 10 6915 5580, Email pumchxuli@163.com

Purpose: Guidelines have not recommended routine transthoracic echocardiography (TTE) for elderly patients prior to noncardiac surgery. We aimed to evaluate the significance of preoperative TTE to predict perioperative cardiac complications (PCCs) for elderly patients with coronary artery disease (CAD) undergoing noncardiac surgery.

Patients and methods: We retrospectively reviewed 2204 patients over 65 years of age with CAD who underwent TTE before intermediate- or high-risk noncardiac surgery in a teaching hospital in China between September 2013 and August 2019. The revised cardiac risk index (RCRI) was assessed. PCCs comprised acute coronary syndrome, heart failure, new-onset severe arrhythmia, nonfatal cardiac arrest, and cardiac death. Logistic regression was used to build the prediction model for PCCs. Discrimination was evaluated using receiver operating characteristic curves, and a nomogram of the predictive model was constructed.

Results: PCCs occurred in 189 (8.6%) patients. Multivariable analysis showed that eight clinical risk factors (age, history of myocardial infarction, insulin therapy for diabetes, New York Heart Association classification, preoperative serum creatinine, preoperative electrocardiogram ST-T abnormality and pathological Q wave, and American Society of Anesthesiologists classification) and five TTE parameters (left atrial anteroposterior dimension, left ventricular ejection fraction, left ventricular diastolic dysfunction, pulmonary hypertension, and regional ventricular wall motion abnormality) were associated with PCCs. The receiver operating characteristic curve for the clinical plus TTE model provided better discrimination for PCCs compared with the RCRI model (area under the curve: 0.731 vs 0.564; $P < 0.001$) and the clinical model (area under the curve: 0.731 vs 0.697, $P = 0.001$), respectively. The clinical plus TTE model was presented as a prognostic nomogram.

Conclusion: Preoperative TTE may help predict PCCs in elderly patients with CAD undergoing noncardiac surgery, and the prognostic nomogram from this study appeared to be useful for the assessment of perioperative cardiac risk.

Keywords: transthoracic echocardiography, elderly, coronary artery disease, noncardiac surgery, perioperative cardiac complication

Introduction

Cardiovascular events are the major cause of mortality among patients undergoing noncardiac surgery.[1] With a growing aging population in China, many elderly patients are complicated with preexisting cardiovascular disease when they undergo noncardiac surgery. The incidence of perioperative cardiac complications (PCCs) is high in elderly patients with coronary heart disease (CAD).[2] Thus, it is crucial to assess cardiac risk for these patients. However, as the most widely used assessment tool for perioperative cardiac risk in noncardiac surgery,[3] the predictive value of the revised cardiac risk index (RCRI) for elderly individuals tends to be low.[4]

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Preoperative transthoracic echocardiography (TTE) is a feasible, noninvasive, reproducible, and cost-effective way to evaluate cardiac structure and function simultaneously.[5] In the cardiovascular assessment guidelines of the American College of Cardiology/American Heart Association and the European Society of Cardiology/European Association of Anesthesiology, preoperative TTE is recommended as a routine preoperative evaluation of left ventricular (LV) function for patients with moderate to severe valvular dysfunction or heart failure (HF).[6–8] However, for elderly patients with CAD, the role of TTE in stratifying perioperative cardiac risk is still controversial. The guidelines of the British Society of Echocardiography have suggested performing echocardiography prior to elective surgery if ischemic heart disease is documented with reduced functional capacity (< 4 metabolic equivalents).[9] Some studies have not supported the routine use of preoperative TTE for cardiac risk evaluation before noncardiac surgery because echocardiographic measurements had no better prognostic abilities than those of clinical factors.[10]

In real-world practice, preoperative TTE is often prescribed for elderly CAD patients prior to noncardiac surgery, by both surgeons and anesthesiologists. Nevertheless, no consensus has been reached on the prognostic value of preoperative TTE. Additionally, no relevant studies have focused on the predictive value of specific parameters. Therefore, it is necessary to investigate the role of preoperative TTE with clinical factors in predicting the perioperative cardiac risk for elderly patients with CAD undergoing intermediate- or high-risk noncardiac surgery. Our aim in this study was to explore a comprehensive and efficient perioperative evaluation strategy for these patients.

Methods

Study Population

This retrospective study was conducted to evaluate the predictive value of TTE for PCCs in elderly patients with CAD. We enrolled patients over 65 years of age with CAD who underwent elective intermediate- or high-risk noncardiac surgeries and TTE examination within 3 months before surgery between September 2013 and August 2019 at Peking Union Medical College Hospital (PUMCH). This study adhered to the provisions of the Declaration of Helsinki, and ethics approval was provided by the Ethics Committee and Institutional Review Board of PUMCH (ethical approval number: S-K1838). The need to obtain patient informed consent was waived by the Ethics Committee and Institutional Review Board of PUMCH. All data were anonymized before analysis.

The cardiac risk of surgery was classified in accordance with the American College of Cardiology/American Heart Association perioperative cardiovascular assessment guidelines. Intermediate- and high-risk surgeries comprised major vascular surgery, peripheral vascular surgery, thoracic surgery, abdominal and retroperitoneal surgery, orthopedic surgery, neurological surgery, head and neck surgery, and transurethral prostatic resection.[7] CAD was confirmed by coronary angiography, history of myocardial infarction (MI), history of coronary revascularization, positive myocardial perfusion scintigraphy, positive exercise stress test, or typical symptoms of angina pectoris with simultaneous signs of myocardial ischemia on electrocardiography (ECG).[11] The exclusion criteria comprised emergency surgery; local anesthesia; low-risk surgery, including eye surgery, superficial surgery, hysteroscopy, and cystoscopic surgery; the presence of severe valvular dysfunction; patients who underwent two or more operations during the same hospitalization; and inadequately recorded TTE parameters for analysis.

TTE Parameters

Before surgery, TTE was performed in all patients using commercially available equipment with a 3.5-MHz phased array transducer (Vivid I; GE Vingmed Ultrasound, Horten, Norway). All examinations were performed and reviewed by cardiologists with advanced training. Left atrial anteroposterior dimension (LAD), interventricular septal wall thickness, LV posterior wall thickness, LV end-diastolic diameter (LVEDD), LV end-systolic diameter (LVESD), and LV ejection fraction (LVEF) were assessed in accordance with the guidelines of the American Society of Echocardiography.[12] LVEDD, LVESD, and LVEF were assessed using the modified biplane Simpson's equation in apical four- and two-chamber views. Mitral inflow was assessed with pulsed-wave Doppler echocardiography from the apical four-chamber view.[13] The mitral peak velocity of early filling (E), the mitral peak velocity of late filling (A), and the velocity of mitral annulus early diastolic motion (e′) were measured. The E/A ratios and E/e′ ratios were calculated for the initial diagnosis of LV diastolic dysfunction. Normal diastolic dysfunction was defined as E/A > 0.8 and < 2 and E/e′ < 10. Grade I diastolic dysfunction was defined as E/A ≤ 0.8 and E/e′ < 10; Grade II diastolic dysfunction was defined as E/A > 0.8 and < 2 with E/e′ ≥ 10 and < 14; and Grade III diastolic dysfunction was defined as E/A ≥ 2 and E/e′ ≥ 14. Left atrial volume index and peak tricuspid valve velocity were considered if the diagnosis or grading was difficult.[14] The estimation of pulmonary artery systolic pressure (PASP) was based on the peak tricuspid valve regurgitation velocity while considering right atrial pressure (estimated by the diameter and collapsibility of the inferior vena cava), as described by the simplified Bernoulli equation.[15] In this study, pulmonary hypertension (PH) was defined as PASP ≥ 35 mmHg, and severe PH was diagnosed if PASP was ≥ 50 mmHg. These definitions were in accordance with the common classification standard in clinical practice, although the PASP value measured by TTE is no longer recommended as the diagnostic and stratification standard of PH in the 2015 European guidelines.[15] Enlarged LV was defined as LVEDD ≥ 55 mm for male patients and LVEDD ≥ 50 mm for female patients, in accordance with the 2019 Chinese adult echocardiography measurement guidelines.[16] Decreased LV systolic function was diagnosed if LVEF was < 50%.[17] The TTE findings were recorded if heart valve dysfunction, aneurysm, LV regional wall motion abnormality (RWMA), or pericardial effusion were detected. All echocardiographic data were averaged for three heart beats.

Data Collection

The electronic medical record system in PUMCH was used in this study. We identified all patients over 65 years of age who were discharged from the surgery department with a diagnosis of CAD and who had a preoperative TTE recording. Further manual comprehensive screening of the patients' medical records was performed to identify those who met the inclusion/exclusion criteria. The detailed patients' medical histories and TTE variables were obtained by careful review of the electronic medical records. We also recorded other relevant perioperative information, namely complication history, preoperative evaluation, New York Heart Association (NYHA) classification, American Society of Anesthesiologists (ASA) classification, surgical information, and postoperative complications. Diabetes mellitus was defined as fasting plasma glucose values ≥ 126 mg/dL or two-hour plasma glucose values ≥ 200 mg/dL during a 75 g oral glucose tolerance test, or hemoglobin A_1c ≥ 6.5%.[18] Hypertension was diagnosed as systolic blood pressure ≥ 130 mmHg, diastolic blood pressure ≥ 80 mmHg, or treatment with antihypertensive medications.[19]

Outcomes

The primary outcome was the occurrence of at least one PCCs intraoperatively or within 30 days postoperatively. PCCs comprised acute coronary syndrome (ACS), HF, new-onset severe arrhythmia, nonfatal cardiac arrest, and cardiac death.[20–25] ACS comprised ST-elevation myocardial infarction (STEMI) and non-ST-elevation acute coronary syndrome (NSTE-ACS). The detailed definitions of the PCCs are shown in the Supplementary Table 1.

Statistical Analysis

Categorical variables are presented as number (%), and continuous variables are presented as the mean ± standard deviation or median and interquartile range, depending on the distribution. The distribution of the continuous variables was determined through visual inspection of the histograms. Logistic regression was used to build two of the prediction models for PCCs. The models were built separately using different parameters: 1) clinical factors, only, and 2) clinical factors and TTE parameters, together. Stepwise variable selection with the Akaike information criterion was used to optimize the multivariable prediction models. Receiver operating characteristic (ROC) curves were used to evaluate the discrimination of the indicators to predict PCCs. The areas under the curve (AUC) of the three prediction models (RCRI, clinical predictor model, and clinical plus TTE predictor model) were calculated and compared using DeLong's test.[26] Calibration was evaluated using Hosmer and Lemeshow's goodness of fit test and calibration plots.

A nomogram, as a simple graphic representation of a statistical predictive model to generate a numerical probability of PCCs, was constructed from the results of the best prediction model based on the AUCs. Statistical analysis was performed using R (R Foundation for Statistical Computing, Vienna, Austria; version 3.5.2) with the "pROC" and "rms" software packages.[27,28] A two-sided *P* value < 0.05 was considered statistically significant except for the Hosmer and Lemeshow goodness of fit test in which a two-sided *P* value < 0.1 was considered significant.

Results

Demographics and TTE Variables

This study screened 4483 patients over 65 years of age with CAD who underwent preoperative TTE, and 2204 patients who met the inclusion criteria were included in the final analysis (Figure 1). The median age was 73.0 ± 5.5 years. The mean LVEF was 66.3% ± 7.7%, and RWMA was detected in 391 patients (17.7%). Of the total number of patients, 348 (15.8%) were diagnosed with moderate heart valve dysfunction, and 1279 (58.0%) were diagnosed with LV diastolic dysfunction, namely 869 (39.4%) with Grade I diastolic dysfunction, 410 (18.6%) with Grade II diastolic dysfunction, and none with Grade III diastolic dysfunction. The patients' demographics, TTE variables, and types of surgery are summarized in Table 1.

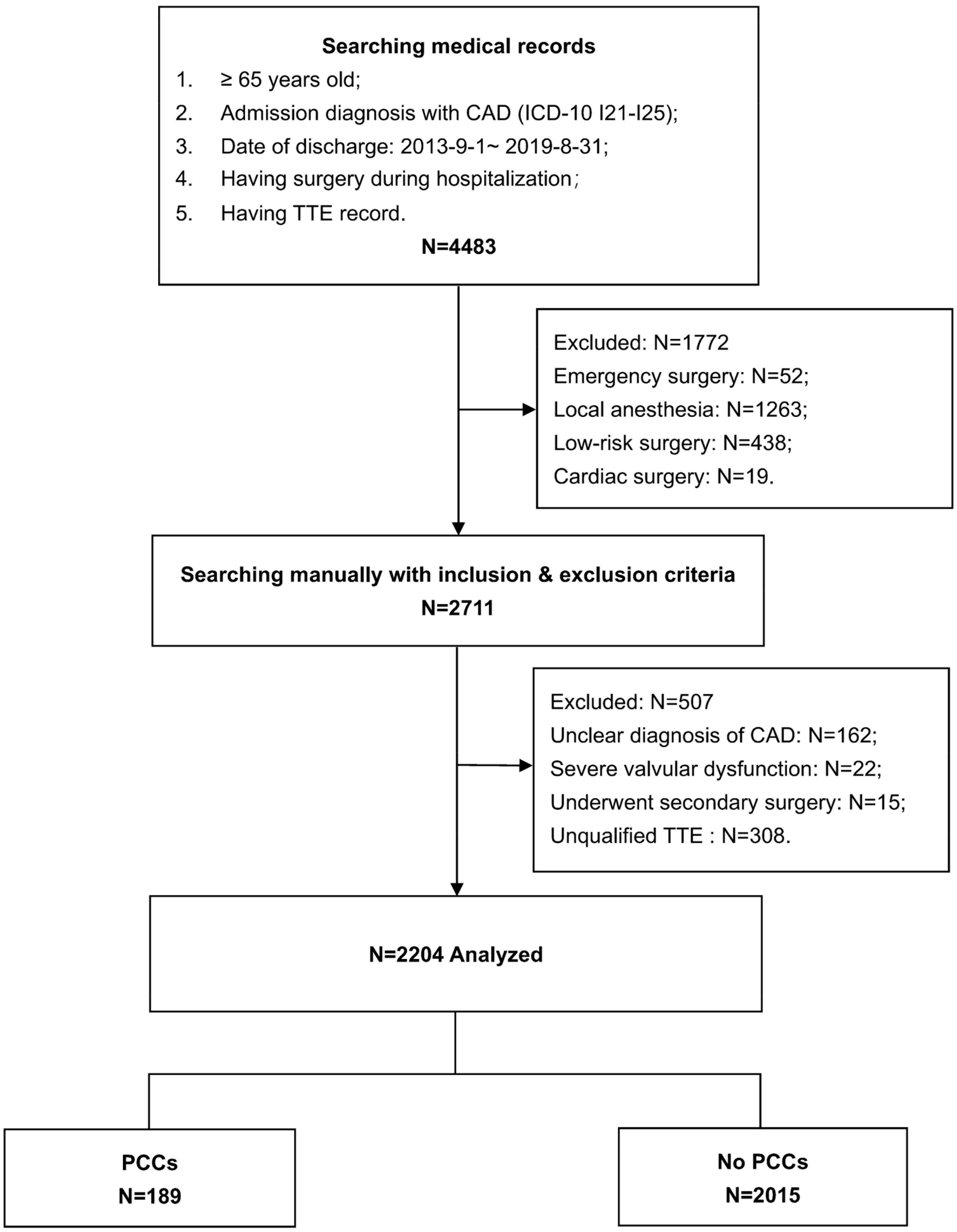

Figure 1 Flow chart of the patient enrollment and analysis.
Abbreviations: CAD, coronary artery disease; ICD, International Classification of Diseases; PCCs, perioperative cardiac complications; TTE, transthoracic echocardiography.

Table 1 Demographics, TTE Variables and Types of Surgery for the Study Population (N=2204)

Characteristics	Mean±SD, or Number (%)
Demographic	
Age (years)	73.0±5.5
Male	1078 (48.9)
BMI (kg/m^2)	24.9±3.6
ASA status	
II	1161 (52.7)
III	862 (39.1)
IV	181 (8.2)
TTE parameters	
Heart valve dysfunction	348 (15.8)
LVEF (%)	66.3±7.7
LV diastolic dysfunction	1279 (58.0)
LV systolic dysfunction	12 (0.5)
RWMA	391 (17.7)
Aneurysm	27 (1.2)
PH	129 (5.9)
Types of surgery	
Main vascular procedures	127 (5.8)
Peripheral vascular procedures	26 (1.2)
Thoracic surgeries	196 (8.9)
Abdominal surgeries	928 (42.1)
Orthopedic surgeries	598 (27.1)
Neurology surgery	42 (1.9)
Head and neck surgeries	230 (10.4)
Other types of surgery	57 (2.6)

Notes: Results are presented as the mean (SD), or n (%). Other types of surgery comprised retroperitoneal surgery, transurethral prostatic resection, and vaginal hysterectomy.

Abbreviations: ASA, American Society of Anesthesiologists; BMI, body mass index (weight/height^2); LV, left ventricular; LVEF, left ventricular ejection fraction; PH, pulmonary hypertension; RWMA, regional wall motion abnormality; SD, standard deviation; TTE, transthoracic echocardiography.

Perioperative Cardiac Complications

A total of 189 patients (8.6%) had PPCs (1 patient intraoperatively, 186 patients postoperatively, and 2 patients both intraoperatively and postoperatively). Among these patients, 8 patients (0.4%) died within 30 days after surgery. The details of the incidences of the PCCs are shown in Table 2. Among the 122 ACS cases, 8 (6.6%) cases were STEMI, and 114 (93.4%) cases were NSTE-ACS. Most complications (N = 164, 86.8%) occurred within the first 3 days after surgery, while 72 (38.1%) developed within the first 24 h postoperatively.

Clinical and Echocardiographic Parameters for PCCs Prediction Modeling

In the logistic regression analysis, which included possibly relevant clinical factors, seven clinical factors were identified in the prediction model (the clinical model). These factors were age, insulin therapy for diabetes, NYHA classification, preoperative serum creatinine (Scr), preoperative ECG ST-T abnormality and pathological Q wave, and ASA classification. Six of these factors had statistical significance ($P < 0.05$) (Table 3).

Next, the preoperative TTE parameters were used in a logistic regression analysis that included all possible clinical factors. The analysis identified eight clinical factors (age, history of MI, insulin therapy for diabetes, NYHA classification, Scr, preoperative ECG ST-T abnormality and pathological Q wave, and ASA classification) and five TTE parameters (LAD, LVEF, LV diastolic dysfunction, PH and RWMA), and these factors were included in the final PCCs prediction model, among which 10 had statistical significance ($P < 0.05$) (Table 3).

Table 2 Detailed Information on the Perioperative Cardiac Complications

PCCs Component Outcomes	N	Proportion in PCCs (%)	Cumulative Incidence in the Whole Population (%)
ACS	122	64.6	5.5
STEMI	8	4.2	0.4
NSTE-ACS	114	60.3	5.2
HF	17	9.0	0.8
New-onset severe arrhythmia	49	25.9	2.2
AF or atrial flutter	33	17.5	1.5
Atrioventricular block	6	3.2	0.3
PSVT	5	2.6	0.2
Frequent premature ventricular	5	2.6	0.2
Nonfatal cardiac arrest	1	0.5	0.0
Total PCCs	189	100.0	8.6

Notes: Patients who experienced more than one PCCs successively were recorded as the first type of PCCs that occurred.
Abbreviations: ACS, acute coronary syndrome; AF, atrial fibrillation; HF, heart failure; NSTE-ACS, non-ST-elevation acute coronary syndrome; PCCs, perioperative cardiac complications; PSVT, paroxysmal supraventricular tachycardia; STEMI, ST-elevation myocardial infarction.

Table 3 Clinical Factors and TTE Parameters Included in the Prediction Model

Variables	OR	95% CI	*P* value
Clinical model			
Age (per year increase)	1.049	1.022–1.077	<0.001
Insulin therapy for diabetes	1.588	1.061–2.330	0.021
NYHA classification (per grade increase)	1.334	1.025–1.735	0.031
Preoperative Scr (per mol/L increase)	1.004	1.001–1.007	0.007
Preoperative ECG ST-T abnormality	1.958	1.376–2.759	<0.001
Preoperative ECG pathological Q wave	1.825	0.905–3.450	0.076
ASA classification (per grade increase)	1.762	1.394–2.223	<0.001
Clinical plus TTE model (final model)			
Age (per year increase)	1.042	1.013–1.070	0.003
MI	1.667	1.016.-2.551	0.047
Insulin therapy for diabetes	1.602	1.068–2.360	0.020
NYHA (per grade increase)	1.276	0.973–1.671	0.077
Preoperative Scr (per mol/L increase)	1.004	1.001–1.008	0.010
Preoperative ECG ST-T abnormality	1.770	1.234–2.512	0.002
Preoperative ECG pathological Q wave	1.826	0.875–3.597	0.093
ASA classification (per grade increase)	1.743	1.374–2.207	<0.001
LAD (per mm increase)	1.028	0.997–1.058	0.072
LVEF (per 1% increase)	0.975	0.951–1.000	0.046
LV diastolic dysfunction (per grade increase)	1.366	1.040–1.792	0.025
PH (per grade increase)	1.669	1.101–2.468	0.012
RMWA	2.089	1.298–3.317	0.002

Notes: Diastolic dysfunction was recorded as four grades: normal (E/A >0.8 and <2 and E/e′ <10; Grade I (E/A ≤0.8 and E/e′ <10); Grade II (E/A >0.8 and <2 and E/e′ ≥10 and <14); and Grade III (E/A ≥2 and E/e′ ≥14). PH was recorded as three grades: normal (PASP <35 mmHg), mild (PASP ≥35 mmHg and <50 mmHg), and severe (PASP ≥ 50 mmHg).
Abbreviations: ASA, American Society of Anesthesiologists; CI, confidence interval; ECG, electrocardiography; E/A, mitral peak velocity of early filling (E)/ mitral peak velocity of late filling (A); E/e′, mitral peak velocity of early filling (E)/early diastolic mitral annular velocity (e′); LAD, left atrial anteroposterior dimension; LV, left ventricular; LVEF, left ventricular ejection fraction; MI, myocardial infarction; NYHA, New York Heart Association; OR, odds ratio; PASP, pulmonary artery systolic pressure; PH, pulmonary hypertension; RWMA, regional wall motion abnormality; Scr, serum creatinine; TTE, transthoracic echocardiography.

ROC Analysis and the Prognostic Nomogram

ROC analysis was performed for RCRI, the clinical model, and the clinical plus TTE model for predicting PCCs. RCRI alone had a poor discriminatory ability (AUC: 0.564, 95% confidence interval [CI]: 0.530–0.597). The clinical model showed

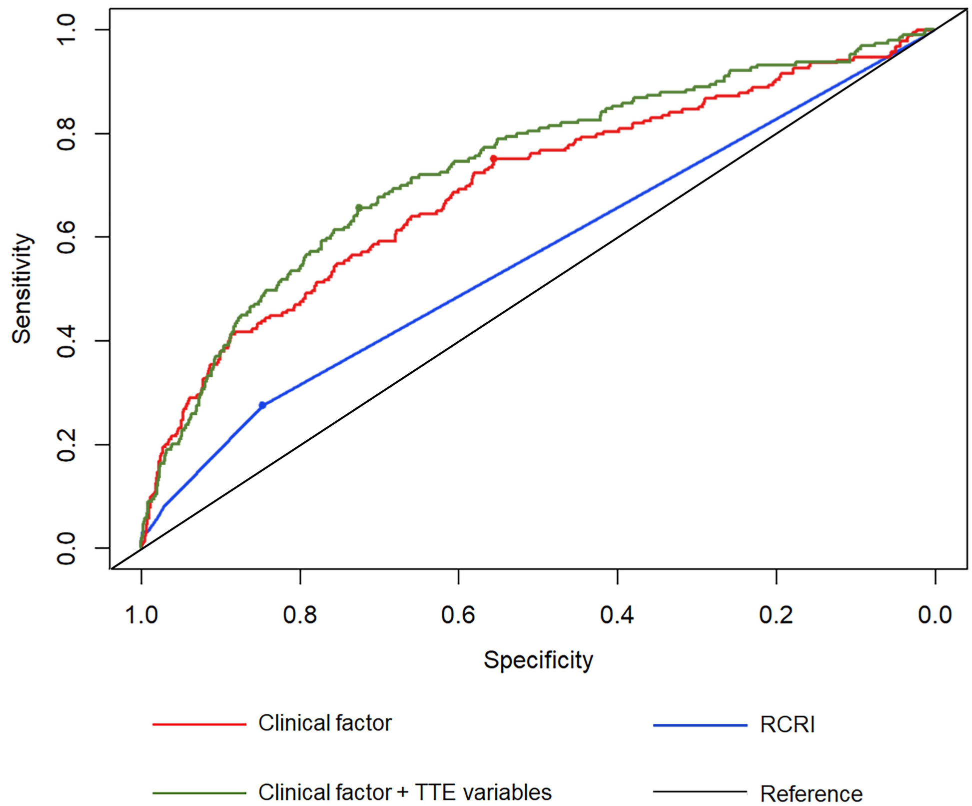

Figure 2 Comparison of the predictive ability of the RCRI, the clinical model, and the clinical plus TTE model.
Abbreviations: RCRI, revised cardiac risk index; TTE, transthoracic echocardiography.

better discriminatory ability (AUC: 0.697, 95% CI: 0.654–0.740) to predict PPCs compared with RCRI alone. When the TTE variables were added to the clinical factors, the AUC increased from 0.697 to 0.731 (95% CI: 0.691–0.771; Figure 2). Using DeLong's test, the clinical plus TTE model (final model) provided significantly better predictive power for PCCs compared with RCRI (AUC: 0.731 vs 0.564, respectively; $P < 0.001$) and the clinical model (AUC: 0.731 vs 0.697, respectively; $P=0.001$). A prognostic nomogram that integrated all of the clinical and TTE parameters in the clinical plus TTE model was then constructed (Figure 3). All P values from the Hosmer and Lemeshow goodness of fit test were > 0.1. Visual inspection of the calibration plots showed that the final model had better calibration compared with RCRI and the clinical model. However, the final model slightly overestimated the risk when the predicted risk was lower than 0.4 and severely overestimated the risk when the predicted risk was higher than 0.5, probably because of the low event numbers in patients with predicted risk > 0.5. Detailed calibration plots are shown in the Supplementary Figures 1–3.

Discussion

How to balance the comprehensiveness of preoperative evaluation with limited medical resources and long wait times is a critical question, especially for high-risk patients. This study demonstrated a novel prediction model composed of anatomical and functional TTE parameters and clinical factors. We used the model to construct an applicable nomogram for predicting PPCs in elderly patients with CAD undergoing intermediate- and high-risk noncardiac surgery.

In this study, PCCs occurred in 8.6% of elderly patients with CAD, mainly within 72 h after noncardiac surgery. NSTE-ACS and new-onset severe arrhythmia predominated. The incidence and characteristics of PCCs were comparable to those in previous reports that involved high-risk populations.[29,30] In the multivariable logistic regression analysis in our study, age, MI, diabetes treatment with insulin, NYHA classification, preoperative Scr, preoperative ECG ST-T abnormality and pathological Q wave, as well as ASA classification, were predictors of PCCs, which was consistent with the predictive factors of RCRI and findings in other studies.[1,2,7,31] Although the current study was limited to elderly

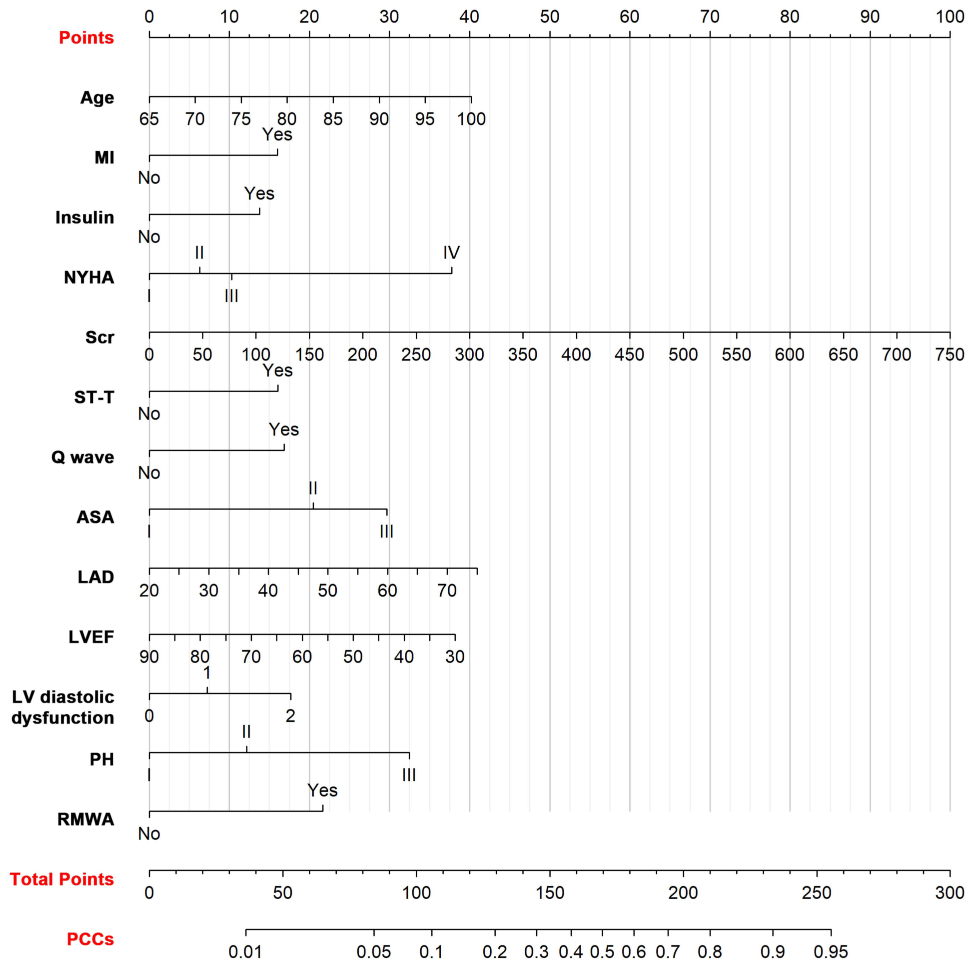

Figure 3 The prognostic nomogram for PCCs in elderly patients with CAD undergoing noncardiac surgery. An individual's value is located on each variable axis, and a line is drawn upward to determine the points received for each variable (corresponding points for each clinical factor: age, MI, insulin therapy for diabetes, NYHA classification, preoperative Scr, preoperative ECG ST-T abnormality and pathological Q wave, and ASA classification; and TTE parameters: LAD, LVEF, LV diastolic dysfunction, PH, and RWMA). The sum of these points is located on the total point axis, and a line is drawn downward to the survival axes to determine the likelihood of PCCs.

Abbreviations: ASA, American Society of Anesthesiologists; CAD, coronary artery disease; ECG, electrocardiography; LAD, left atrial anteroposterior dimension; LV, left ventricular; LVEF, left ventricular ejection fraction; MI, myocardial infarction; NYHA, New York Heart Association; PCCs, perioperative cardiac complications; PH, pulmonary hypertension; RWMA, regional wall motion abnormality; Scr, serum creatinine; TTE, transthoracic echocardiography.

patients, the incidence of PPCs increased with age. Similarly, in a prospective study of patients over 60 years of age who underwent major noncardiac surgery, age was also recognized as a risk factor for postoperative adverse cardiovascular events.[32] The short- and long-term prediction significance of ECG abnormalities in addition to clinical characteristics has been identified, especially in CAD patients.[7,33] The presence of preoperative ST-segment abnormalities and pathological Q waves calls for further examination.

Among the five predictive TTE factors included in the nomogram, two were associated with LV systolic function (LVEF and RWMA). LV systolic function, represented by LVEF and RWMA, is the most concerning item clinically. A number of studies have demonstrated an independent positive correlation between decreased LV systolic function at rest and perioperative cardiovascular morbidity and long-term mortality, especially in high-risk noncardiac surgery.[34,35] Owing to surgical stress, pain, and blood loss, perioperative myocardial oxygen consumption increases, with concomitant tachycardia, and coronary blood flow decreases. The oxygen supply-demand mismatch is more likely to lead to myocardial ischemia and other adverse cardiovascular events in patients with decreased LVEF and impaired cardiac reserve than in patients without these conditions.

LV diastolic dysfunction is reported to be common in elderly patients. In a previous study, nearly half of the elderly patients who underwent elective surgery had LV diastolic dysfunction with preserved LV systolic function.[36] In our results, 58% of the patients were diagnosed with LV diastolic dysfunction and most were asymptomatic, with normal LVEF. For patients with CAD or hypertension, LV diastolic dysfunction may be due to concentric remodeling and dilatation of the LV. These changes cause impaired LV compliance, representing not only HF but also susceptibility to perioperative myocardial damage and arrhythmia.[37] Our results clearly demonstrated that the incidence of PCCs increased with higher-grade LV diastolic dysfunction, although HF accounted for only a small percentage of the PPCs (9%). In a prospective cohort study of 1005 vascular surgery patients, asymptomatic LV dysfunction (defined as E/A < 0.8) predicted 30-day and long-term cardiovascular outcomes.[34]

Among the TTE parameters, increased LAD predicted PCCs. Left atrial remodeling defining as an increment in LAD as well as advanced age were independent predictors for developing atrial fibrillation (AF).[38,39] A retrospective study found that left atrial dilatation was a predictor of AF after noncardiac surgery.[40]

In this study, the presence of PH was also a predictor of PCCs. In a study of 17,853,194 hospitalizations for major noncardiac surgery, PH developed in 0.8% of the patients and was associated with increased morbidity and mortality.[41] Patients with diseases commonly associated with PH, such as chronic obstructive pulmonary disease, obstructive sleep apnea-hypopnea syndrome, and thromboembolic disease, should receive particular attention regarding the estimation of pulmonary artery pressure.

To our knowledge, this study was the first to construct a quantitative nomogram integrating TTE parameters and clinical factors to predict the probability of PPCs for elderly patients with CAD before noncardiac surgery. The nomogram provided a better predictive effect than that of the model which included clinical factors alone. With both conventional clinical assessment and the preoperative TTE information, the nomogram in this study could provide rapid computation of possible prognosis through user-friendly digital interfaces, with high accuracy, to aid clinical decision-making. For patients who are indicated as being high-risk in the nomogram, the risk-benefit ratio of surgical procedures should be evaluated to determine the surgical strategy. Once an operation is scheduled, perioperative evaluation and optimization should be especially strengthened, such as blood glucose and blood pressure management, nutrition support, and cardiopulmonary function improvement. Additionally, these patients are more susceptible to the effects of excess perioperative fluid administration. Invasive hemodynamic monitoring and goal-directed fluid therapy should be considered perioperatively,[9] as well as multimodal analgesia and other protocols of Enhanced Recovery After Surgery (ERAS) to minimize the perioperative stress response.

It's worth noting that the TTE predictive factors in this study are all basic factors that are feasible to evaluate using focused echocardiography. A basic point-of-care TTE could be performed by anesthesiologists in the preoperative holding area if elderly patients do not receive formal TTE preoperatively owing to time constraints or cost considerations, to balance the avoidance of surgical delay with the requirement for TTE. Overall, the method proposed in our study could be considered a useful tool to predict PPCs for elderly patients with CAD.

This study has several limitations. First, this was a retrospective cohort study. All patients who underwent preoperative TTE with available reports were included, which may have led to selection bias. Some patients with CAD did not receive preoperative TTE examination owing to the presence of stable symptoms or because of surgery scheduling. Meanwhile, it is possible that the perioperative management for patients with severe abnormal TTE findings has been changed, which would tend to weaken the association between TTE parameters and PCCs. Second, our study offers no information about the patients' N-terminal pro-B-type natriuretic peptide concentrations or their intraoperative hemodynamic status. N-terminal pro-B-type natriuretic peptide plays an important role in detecting LV dysfunction, and hemodynamic stress is known to increase LV filling pressure and improve cardiac workload.[42] Therefore, a multicenter prospective study with a larger population that includes data for the necessary factors (laboratory, clinical, and TTE parameters, and evaluation of CAD progression) is warranted to demonstrate the predictive value of TTE as a simple and noninvasive tool before noncardiac surgery.

Conclusion

We demonstrated that preoperative TTE, in conjunction with clinical factors, was useful for predicting the cardiac risk for elderly patients with CAD undergoing noncardiac surgery. The prognostic nomogram, which integrates clinical and TTE parameters, is feasible and useful for perioperative cardiac risk assessment.

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Disclosure

The authors report no conflicts of interest in this work.

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